Hello Industrie 4.0
_Glossary

EN

»Robotics, automation technology and digitization will shape the next half-century in the same way that the Internet, smartphones and computers have shaped the past half-century. Our grandchildren will grow up as the first generation ›R‹ of ›Robotic Natives‹ – and we have to start taking responsibility for this today!«

Dominik Bösl
Corporate Innovation Office
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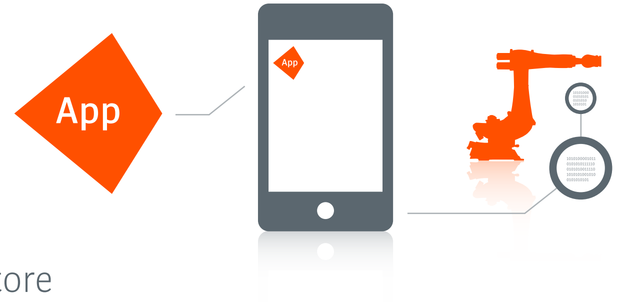
_The future of automation is being written today. What is meant by "robotic natives"? What role does "decentralized intelligence" play in Industrie 4.0? And why will things in the future get "digital shadows"? The digital transformation and the change that this will bring forth in our worlds of production raise a lot of questions. We have put together this small compendium of important terms related to Industrie 4.0 for you. From A for app store to Y for youBot.



App Store

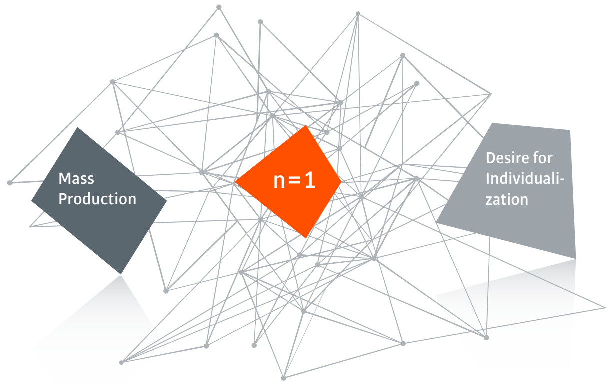
_New capabilities on demand. Already equipped for the future: for generations, KUKA robot controllers have featured a modular and scalable configuration on the basis of mainstream technologies. KUKA has thus created the foundation for making smart tools available via app stores and marketplaces. Intelligent digital forms or complete applications, such as those familiar today from well-known app stores for smartphones, tablets or computers, and which endow robots with new capabilities and functions on demand at the click of a mouse. For example, programs that only require entry of the desired parameters. With regard to Industrie 4.0, the immediate availability of new production capabilities will open up a whole new dimension of versatility for robots.

Artificial Intelligence

_Machines as intelligent partners. Artificial Intelligence (AI) is the step required for implementing the fourth stage of the robotic revolutions postulated by KUKA. It presupposes that machines, information systems and robots are capable of replicating human intelligence in part or as a whole. In the fields of service robotics and home assisted living, these intelligent machines with their cognitive and sensitive capabilities will become increasingly important as helpers for humans.

Today, these systems are still fully dependent on programming by humans. As the degree of autonomy of the systems increases, however, the issue of responsible management of artificial intelligence will become ever more pressing. As soon as the first robots make decisions entirely on their own, this must done in compliance with Asimov's laws at all times. These are:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.



Batch Size 1

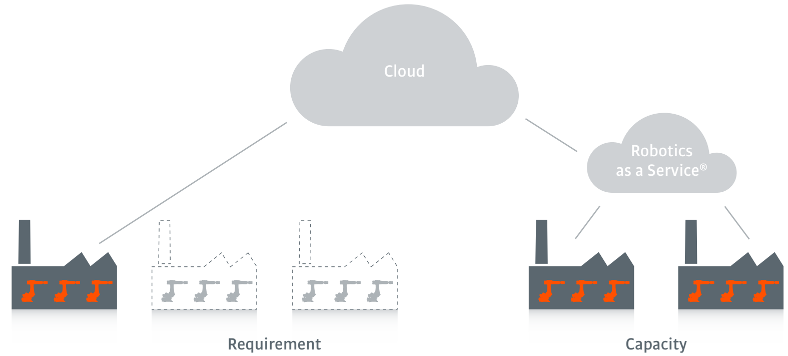
_Unique, one-off products for everyone. Industrie 4.0 is creating the basis for implementing the highest levels of customization – all the way down to batch size 1 – within industrial manufacturing. This means high-quality, single-piece production at the price of current, uniform, mass-produced goods. The networking of all systems involved in production, and their extreme flexibility, will make the fulfillment of individual customer requirements a matter of routine in the smart factory. While the desire for customized products is already a megatrend today, it will develop to become one of the decisive competitive factors in the near future. This trend not only offers new market opportunities for products, but also gives traditional industrial nations the chance to return previously outsourced production capacity to locations in high-wage countries.

Big Data

_Data are the new oil. The term “Big Data” refers to quantities of data that are too large or too complex, that change too quickly or are too weakly structured for them to be evaluated with manual and conventional methods of data processing. In this context, experts talk about an inconceivably large data volume of currently more than 8 zettabytes – with an increasing tendency. A substantial proportion of this already comes from the Internet of Things (IoT) and from the ever more numerous sensors in machines and vehicles. Data are increasingly being generated in real time. In connection with Industrie 4.0, however, it is the ability to evaluate and process this flood of data that is of paramount interest. That is how Big Data become Smart Data. The challenge is therefore not only for IT systems to be able to handle heterogeneous data correctly but also for them to analyze the data in order to create a reliable basis for business decisions – preferably in real time. Only in this way can processes be controlled intelligently and adapted to changing parameters. Taking the metaphor further, Big Data is thus the new oil of the 21st century.

Cloud Robotics

_Shared intelligence. Nowadays smartphones, tablets and computers utilize data and processing power from the cloud as a matter of course. In the context of Industrie 4.0, robots too will be able to access decentralized data in networks or in the cloud, thereby significantly boosting their performance and flexibility. The robot itself will only require a small chip to control functionality, motion and mobility. For the task at hand, specific services will be retrieved from the cloud or individual robots networked on an ad hoc basis to form temporary production teams. In this way, specialists will become universalists that can be used for a wide range of different manufacturing processes. Cloud robotics enables the implementation of a broad spectrum of different industry-specific applications via “Robotics as a Service®”. Another effect of the cloud: robots learn from one another. If one robot encounters an obstacle, for example, it posts this information to the connected systems, which can use it to respond intelligently to the obstacle.



Collaborative Robots

_Hand in hand. Collaborative robots – sometimes also known as “cobots” for short – are robots that are capable of human-robot collaboration (HRC) and work hand in hand with their human colleagues. As collaborative robots operate without physical safeguards, they have to permanently calculate the risk of colliding with humans, constantly checking this via the robot controller. The strict safety requirements have been redefined in the revised EN ISO 10218 standard, parts 1 and 2, and in the ISO/TS 15066 specification initially drafted in 2010. Besides the robot itself, the standard also covers the adapted end-of-arm tooling with which the robot performs its tasks, and the objects moved with it. With the LBR iiwa, KUKA has made the world’s first series-produced, collaborative lightweight robot for industrial applications ready for the market, thereby proving that the visions of Industrie 4.0 can be turned into reality.

Committees

_Strong alliances with KUKA. As a leading supplier of intelligent automation solutions, KUKA is directly involved in Industrie 4.0 and sees itself as responsible for forming strong alliances with the goal of actively shaping the factory of the future together with other key players. That is why KUKA is a member of all major

national and international advocacy groups and committees, such as the Industrie 4.0 Platform, the Industrial Internet Consortium IIC, the OPC Foundation, the industry association VDMA and the associations BITKOM and VDE. As a trailblazer for Industrie 4.0, KUKA is a sought-after interlocutor for decision-makers in the worlds of politics, research and business.

Cyber-Physical System (CPS)

_Physical world meets virtual world. A cyber-physical system (CPS) is a "thing" in the Internet of Things (IoT). It is a combination of mechanical, electronic and software components that communicate via a data infrastructure such as the Internet, react flexibly to external influences and exchange data with information systems and other CPSs. In future manufacturing facilities, cyber-physical systems will communicate with intelligent, networked industrial production and logistics units – also known as cyber-physical production systems (CPPS). The CPSs exchange information, trigger actions in production and reciprocally control themselves autonomously. This enables industrial processes in manufacturing, engineering, use of materials, supply chain management and life cycle management to be fundamentally restructured and optimized.

Data Ownership

_Who owns the data? The data belong to the originator. A principle that is regrettably contested in the cloud. The open exchange of data and information, however, is a vital ingredient of Industrie 4.0. To put this on a secure footing, it is necessary to create platforms that comply with high ethical standards conforming to German data protection laws. Particularly with a view to the horizontal networking of various companies within a production process, the question of data sovereignty is of central importance. With cloud solutions meeting the highest data security standards, KUKA offers unique platforms on the basis of which customers can exchange their own data with others or enrich them with new intelligence and additional information.

Decentralized Intelligence

_Intelligence evolves in the swarm. Decentralized intelligence will play an important role in Industrie 4.0: all parties can communicate with one another – workpiece with machine, machine with machine or with higher-level processes. No central "brain" will control and monitor the things, but rather autonomous production units will carry out this function for both heterogeneous and homogeneous teams. Decentrality makes for greater flexibility and quicker decisions. Intelligence evolves in the swarm or through joint networking with the cloud.

Demographic Change

_Society is getting ever older. In principle, the term "demographic change" is a neutral reference to any alteration in the age structure of a society. At present, however, it is being widely used as a synonym for increasing overaging in the industrial nations. A trend that is diametrically opposed to the rapid growth of the global population. By the year 2020, more than half of the German population will already be over 50 years of age. An ever smaller number of people in employment will have to generate the entire productive output for the social systems. This challenge can only be met if the remaining workers become considerably more productive than all generations before them. At the same time, opportunities must be created for older, experienced employees to participate in the world of work for longer. In order to make new working environments both highly productive and ergonomically beneficial for the labor force, KUKA is developing central key technologies for Industrie 4.0: collaborative robots, mobile assistance systems, autonomously controlled vehicles and smart, digitized automation solutions that support humans in the work setting, easing the workload in a variety of ways.

Digital Shadow

_Virtual image of real things. The digital shadow is a digital image of a real object. These data contain both the current status and the desired status of the object, the possible ways and processes for achieving the desired status, and the history of what the object has already gone through. It is only the combination of a digital shadow and a physical object that results in a smart thing. Every physical product can be manufactured more efficiently and with higher quality in the digitized production facility if a digital shadow has been created for it and it bears its own specific DNA.

Digital Supply Chain

_Transcending all boundaries. The digital supply chain merges the major business processes of all parties involved – from the suppliers to the manufacturer and the end customer. The potential of a digitized value creation chain lies primarily in the acceleration of the production and logistics processes, the reduction of effort for data acquisition and the optimization of data security and consistency. With integrated networking, the digital value creation chain is able to overcome current media discontinuity. One example from the field of procurement: where a steel-processing company previously had to activate a complicated process via different media for purchasing and replenishment, in the future purchasing will be automated on the basis of predefined parameters. Companies today are already making use of digital value creation chains to optimize individual production islands and processes within their organization. In the factory of tomorrow, the digital supply chain will also encompass global procedures across company boundaries, controlling them largely autonomously. As the most flexible machine ever conceived by man, the robot plays a central role in the digital supply chain. In its function as the core component of intelligent automation solutions, it increases the entrepreneurial freedom of action, secures competitive advantages, speeds up production processes and assures quality in the long term.

Digitization

_Potential of the digital transformation. Converting real products and analog sequences into digital data and processes is referred to as digitization. In Industrie 4.0, people, machines and industrial processes are networked on the basis of cyber-physical systems incorporating state-of-the-art information and communications technology. In this context, the intelligent exchange and interpretation of data determine the entire life cycle of a product: from the idea to development, manufacturing, use and maintenance through to recycling. Production and logistics processes will be globally networked beyond the factory gates in the future for the purpose of optimizing the flow of materials, detecting non-conforming parameters at an early stage and enabling a highly flexible reaction to changing customer requirements and market conditions.

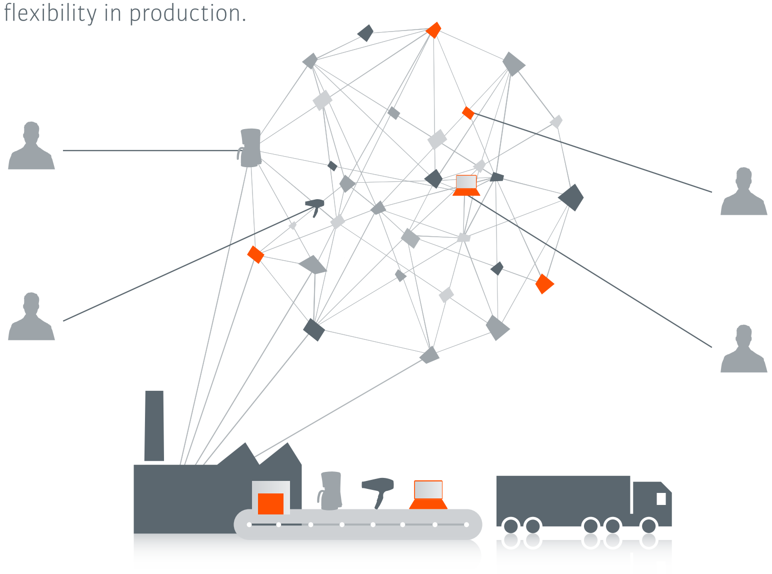
flexFELLOW

_The KUKA flexFELLOW automation unit can be moved manually and allows ad hoc localized variation of the degree of automation in production. Without the need to alter the production layout, for example, the KUKA flexFELLOW is able to open the safety doors at machines, which it can then load and unload independently. It can also assist the operator in performing work steps in ergonomically unfavorable situations. In alternating operation, humans and robots can ideally complement one another. The combinability of manual and automatic tasks means that production can be optimally adapted to the specific requirements.

Flexibility

_Flexibility in all dimensions. Flexibility is the ability to react quickly to changing influences. In the smart factory, utmost flexibility results primarily from the combination of IT technologies, such as the Cloud and Big Data, with intelligent, generic production units incorporating robots and autonomously controlled mobile units. The factory of the future will not have any predefined routes or rigid processes. Mobile units will equip robots "on the fly" with other tools, enabling them quickly to carry out new tasks or process other workpieces. The smart

factory is therefore able to manufacture different products or product versions without any significant retooling times. It thus completely redefines the concept of flexibility in production.

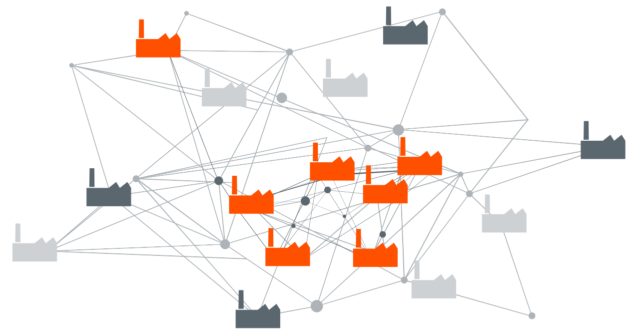


Home Assisted Living

_Living independently – even in later life. Our society is becoming ever older: in 2035, one in every three Germans will be over 60 years of age. Everybody wants to stay autonomous and active for as long as possible when old, however. Home assisted living enables the elderly to continue an independent life within their own four walls. Besides service robots which take care of household activities, and smart home applications, services in the medical and nursing sectors will be a part of daily life in the future. With the aid of intelligent robots, rehabilitation treatment, for example, will be possible at home. Mobility assistants will help people to remain agile into old age, improving the quality of millions of lives.

Horizontal Integration

_Dynamic company networks. Exact coordination is not only indispensable for internal process optimization within a company, but also between all companies involved in the value creation chain. This horizontal integration – networking between different enterprises – is the starting point for the flexible design of their shared value creation processes.In the era of Industrie 4.0, companies will form dynamic networks in the future, linking order-specific and product-specific capacities in virtual production communities. Current data from the production-relevant processes will enable fast and precise reactions – for instance to planning changes or unexpected events occurring inside or outside an individual company. Production and logistics processes adapt to the real situation in real time, boosting the long-term flexibility and efficiency of the companies acting within an integrated concept.



Human-Robot Collaboration

_The best of two worlds. Until now, industrial robots always worked separately from humans in specially safeguarded protected spaces. KUKA has broken down this barrier with a new generation of collaborative industrial robots, such as the sensitive lightweight robot LBR iiwa. With human-robot collaboration (HRC), KUKA is thus combining the best of two worlds: humans with their superior creativity and cognitive abilities and the robot with its greater repeatability, strength and precision. In this way, the robot becomes the third arm of the human operator. This new form of collaboration opens up previously inconceivable possibilities for the smart factory of the future.

Individualized Production

_Meeting every customer requirement. Individualized, or customized, production refers to the concept of an intelligent, highly automated production system that allows high variance and dynamism in the product range with production costs at the level of mass production. The goal is to resolve the conflict between the customer's desire for individualization and the process efficiency of production in an industrial setting. A batch size of 1 is the highest level of customized production. Besides proprietary solutions in the automotive sector, Industrie 4.0 with its universally networked production environments represents the world's most advanced approach for implementing customized production.

Industrie 4.0

_Production meets digitization. Industrie 4.0, Smart Production or Internet of Things – even if the names and terms used vary from one country to another, they all share the same goal. What is called for here is nothing less than a long-term transformation of our global perception of industrial production through the seamless connection of the digital and real worlds. KUKA is at the interface between these two worlds and is playing a decisive role in advancing this transformation as a thought leader and trailblazer for Industrie 4.0. It was back in the 1990s that KUKA as a first mover recognized the potential to be gained by combining the world of IT with conventional automation technologies. The company was also the world's first robot manufacturer to develop open, interoperable and flexible systems on the basis of standardized mainstream technologies and to make them ready for the market. In collaboration with experts from diverse sectors, KUKA is now already implementing highly flexible, digitized manufacturing processes that will open up new opportunities in a competitive environment and lastingly change the way we work and produce.

Internet of Automation (IoA) / Internet of Robotics (IoR)

_Basis for efficient production. Both the Internet of Automation (IoA) and the Internet of Robotics (IoR) make use of defined open communications and data standards to network interoperable production processes even across company boundaries. In the IoR for example, KUKA robots, the KUKA App Store, connectivity and monitoring tools are networked to form a highly efficient production environment in which analog and digital devices can easily communicate with one another. In the near future, it will be possible for all the cyber-physical elements involved in the automated manufacturing process to be networked in the IoA and to communicate with the IoR.

Internet of Things (IoT)

_Everything communicates with everything else. Like Industrie 4.0, the Internet of Things (IoT) presupposes a network of physical objects – devices, vehicles, buildings and other items – which are fitted with electronic components, software and sensors, all of them being linked interoperably via the Internet. Unlike Industrie 4.0, the IoT rather non-selectively refers to all things that could be connected to the cloud. The IoT thus also encompasses the private domain, including, for instance, the already well-known "smart home" applications.

Strictly speaking, the smart factories of Industrie 4.0 along with all their production and logistics processes are a part of the IoT. Experts forecast that the IoT will comprise 50 billion objects by the year 2020.

Interoperability

_Everything works together. Interoperability (IOP) describes the ability of an object, device or machine to communicate with other things in the network. It must be able to do so regardless of whether the devices are from the same or different manufacturers. Interoperability is a fundamental precondition for creating a layer that enables cyber-physical systems to be interconnected such that interactions are possible without the participants knowing which technologies the implemented devices are based on. It is also the basis for the capability of the things in the network to communicate without any restrictions and to act intelligently as a swarm.

KMR iiwa

_New horizons. Shorter response times and greater flexibility going beyond full automation: these are the requirements of markets that are changing at an ever faster pace. The industrial manufacturing of the future will require modular, versatile and, above all, mobile production and manufacturing concepts. That is why the KMR iiwa unites the sensitive and compliant LBR iiwa lightweight robot with KUKA's mobile platform technology to form a new, intelligent and fully mobile combination that can work in the vicinity of humans. Just like humans, the KUKA Mobile Robots (KMR) can track moving workpieces, move around them freely and link solitary production islands to form new production units.

KMR QUANTEC

_Large-dimension e-mobility. Anyone thinking big and looking for flexible mobility will find the perfect powerful partner in the KMR QUANTEC. The combination of KUKA six-axis robots, mobile platforms, high-performance energy storage units and industrial-grade components creates a mobile solution for virtually any scenario. Despite its strength, the KMR QUANTEC is characterized by outstanding precision and maximum electromobility. Its small power plant supplies it with electricity for a full 8-hour shift. The position and number of robots installed are variable, as too are the size and payload capacity of the platform. Grippers, power-hungry tools and special equipment can also be transported on the KMR QUANTEC and continuously supplied with power.

LBR iiwa

_Robotic colleague. KUKA is starting a new chapter in the history of industrial robotics with the lightweight robot LBR iiwa (intelligent industrial work assistant). As the first series-produced sensitive robot for human-robot collaboration (HRC), the LBR iiwa is tapping new applications that were previously closed to automation. Thanks to its sensory capabilities, it can intuitively learn new tasks on an ad hoc basis, simply through being guided by its human partner. The machine becomes a “robotic colleague”. It works hand in hand with the operator, thereby enabling him to work more efficiently, more ergonomically, more precisely and with greater concentration. As a robot that can genuinely be deployed universally, it is defining new standards on the road to the fourth industrial revolution.

Logistics

_Now. Everything. Always. Customized products and same-day delivery – customers have a growing expectation that everything will be available in all places, at all times. This ubiquity places the utmost demands on the logistics and process chains and is increasingly embracing the stationary retail sector and the structure of merchandise flows. The boundaries between individual delivery channels are successively vanishing and modern distribution centers are often being set up directly in metropolitan areas thanks to the reduced space requirements. Changes that can only be addressed through highly transparent, digitized networking of production and logistics. In this context, KUKA sees itself as a solution provider translating the individual requirements of the market participants into flexible, networked and software-supported logistics concepts.

Machine Learning

_Knowledge through experience. Intelligent machines garner their knowledge through experience. In the case of networked machines, it is irrelevant whether the experience is their own or originates from swarm intelligence. An artificial system always learns by comparing the desired objective and any anomalies that occur. It can recognize correlations, patterns and general rules, draw conclusions from them and modify its future behavior, this synthetic process being referred to as machine learning. Especially in unstructured environments and with highly flexible processes like Industrie 4.0, machine learning in a swarm or in the cloud is an effective method of adapting production processes intelligently and autonomously to the individual framework practically in real time.

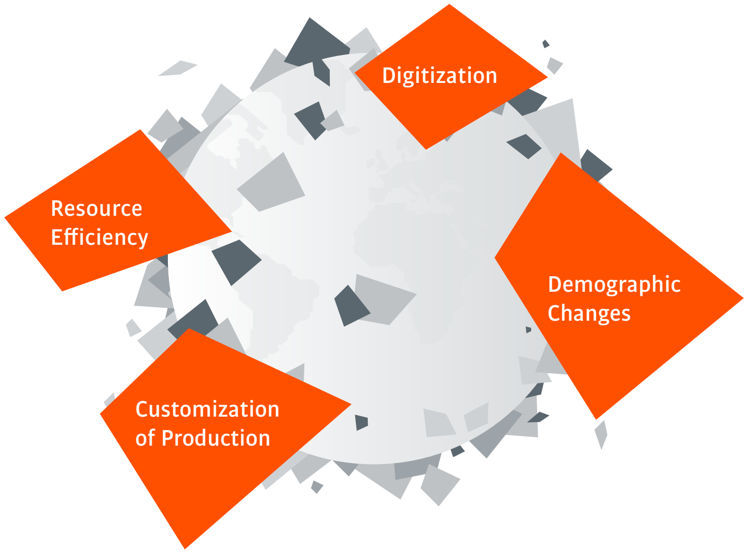
Manufacturing as a Service / Robotics as a Service®

_Access rather than possession. Digitization has substantially changed the approach to physical possession. It is increasingly being replaced by temporary access to goods or services. The best example: music streaming. What has already become an everyday situation in many consumer segments will also revolutionize the industrial environment over the next few years. As the name suggests, “Manufacturing as a Service” will see manufacturing processes purchased as services: the machine itself does not change ownership – payment is made for the performance of the machine only. What applies to complete production systems will, in the future, also apply to individual elements within a manufacturing facility, for example to robots. On the basis of a “pay-per-use” model, it will not be the physical object itself that is purchased in conjunction with “Robotics as a Service®”, but rather its performance, such as weld spots in vehicle body production, for instance. The smart factory of the future integrates these services seamlessly

into its production processes and thus has the capability of reacting to varying capacity requirements and goods flows exceedingly flexibly and efficiently while conserving resources at the same time.

Megatrends

_What makes the world go round. Customization, digitization, responsible use of natural resources and demographic changes are the megatrends that will need to be mastered in the coming decades. With a forecast world population of 8 billion by the year 2025 and 10 billion by 2060, ever more customer requirements of increasing diversity will need to be satisfied. At the same time, demographic changes will be confronting industrialized and emerging countries with economic and social challenges over the long term. Humanity is thus facing a fundamental paradigm shift which will undoubtedly have far-reaching consequences for our worldwide economic systems. That is why Industrie 4.0 does not describe a purely technical innovation scenario but rather a way in which intelligent technology can help to overcome the global challenges of the 21st century. As a thought leader and trailblazer for Industrie 4.0, KUKA is working on production environments which increase economic efficiency while also using resources responsibly, which make high-quality goods more affordable and which are instrumental in sustainably improving human working conditions in factories.



Mobility

_Robots on the advance. The production of the future requires greater flexibility – for both faster manufacturing and customized products. One indispensable prerequisite for creating a higher degree of flexibility in industrial environments is greater mobility. This can be achieved by means of episodic, periodic or permanent mobility concepts that each bring about acceleration in industrial production in their own specific ways. For this reason, KUKA is paving the way for this key technology with platforms that can move intelligently and autonomously in order to transport things or machine workpieces. They can find their own way if necessary, aligning themselves with workpieces to within a millimeter or even moving the robot to them. They are also capable of responding autonomously and adaptively to changing conditions in complex logistics and production chains. Mobile automation solutions from KUKA show today what the future holds in store for highly flexible production in Industrie 4.0.

Monitoring & Stream Analytics

_Data in real time. Monitoring and stream analytics compare and analyze data that are available to the smart factory from diverse sources – devices, sensors, infrastructure, etc. In real time they make comparisons with data records from the past and recognize anomalies, which can be categorized as faults with the aid of machine learning. On this basis intelligent systems can initiate immediate countermeasures and generate forecasts and recommended actions for the future.

omniMove

_Strong on the move. Wherever size, load-bearing capacity and precision are required, the KMP omniMove heavy-duty mobile platform is in its element. Individually or as part of a fleet, the KMP omniMove can effortlessly move beneath, and lift, workpieces weighing more than 90 tonnes and move in any desired direction with millimeter precision from a standing start, thanks to the omnidirectional omniWheels. The KMP omniMove can move autonomously, under guidance along a programmed path or conventionally under manual control.

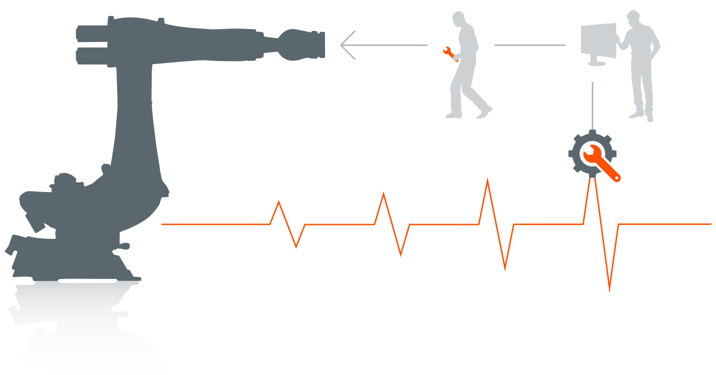
People First

_Production and products for people. In the factory of the future, the focus of thought and action will shift to the human worker with his changed requirements,

desires and capabilities. Networked and flexible production technologies combine the cost advantages of mass production with the customization potential of craft manufacturing. This means that the customers' desire for high-quality individualized products does not lead to higher prices, as is currently the case. But humans are at the center of the future world of goods not only in their role as customers. Intelligent robots that collaborate with humans, and mobile assistance systems will improve the world of work in many different ways. They handle heavy loads, carry out activities that are not ergonomic or are simply too dangerous for people and perform tasks which require levels of precision and speed of which humans are not capable or which are cognitively stressful.

Predictive Maintenance

_Eliminating static maintenance intervals. Dependable production planning and maximum machine availability through the avoidance of unscheduled down-time are the practical advantages of what is internationally known as predictive maintenance. On the basis of real-time data, all relevant parameters of the machines involved in the manufacturing process are acquired and evaluated for anomalies by means of stream analytics. In a subsequent machine learning process, specific fault patterns and the causes of a problem are detected in good time. This results in fewer rejects and maximum availability over the entire life cycle of the production line. The requirements on machine operating times vary depending on the specific branch of industry and its product cycles. While this could be up to 30 years in the aerospace sector, it is a matter of just a few months in the case of fast-moving goods, such as smartphones. With the aim of enabling an accurate assessment of the future performance of the machine or one of its components, intelligent predictive maintenance systems interconnect the largest possible amount of data from decentralized sources for the purpose of analysis.



Re-Shoring

_Available is the new cheap. Whereas in the past purchase decisions were often primarily made on the basis of the lowest price, in the future it will be the product that is available most quickly and with a high level of customization that will be at the top of consumers' shopping lists. This necessitates new manufacturing and marketing methods and structures that will only become possible as a result of networked production in smart factories. Short distances will be an important factor in achieving fast availability. Due to the high degree of automation, production steps that are currently outsourced to low-wage countries can be repatriated to high-wage countries in a process known as "reshoring". Irrespective of wage structures, intelligent automation allows cost-efficient and high-quality production in the vicinity of the consumers.

Resource Efficiency

_Sustainable production. The ability of humanity to handle the future will be determined by a responsible and sustainable approach to natural resources. In a just world, it may be assumed that ever more people will want to be supplied with ever better products. Flexible, intelligent and networked production as envisaged in Industrie 4.0 offers the opportunity of using raw materials more efficiently and more sustainably along the entire value creation chain and recycling them to a great extent for the sake of the planet.

Robofactory

_Craftsmanship meets robotics. Unlike a conventional factory, with its high degree of uniform mass production, craft manufacturing combines the virtues of skilled craftsmanship with a low level of mechanization.

Craft-manufactured products convince with high quality and a distinctly unique character. Robofacturing unites the advantages of craft manufacturing with the low price of a mass product, making individual and high-quality products affordable for large parts of the global population.

Robotic Governance

_Creating a responsible future world for generation "R". Robotic governance is a concept which, among other things, considers the ethical/moral, socio-cultural, socio-political and socio-economic effects of robotics on society and provides a framework for solving problems resulting from these changes. The governance principles include accountability, responsibility, transparency of structures and fairness. In this way, robotic governance helps to create a sustainable and responsible future world for the upcoming generation "R".

Robotic Natives

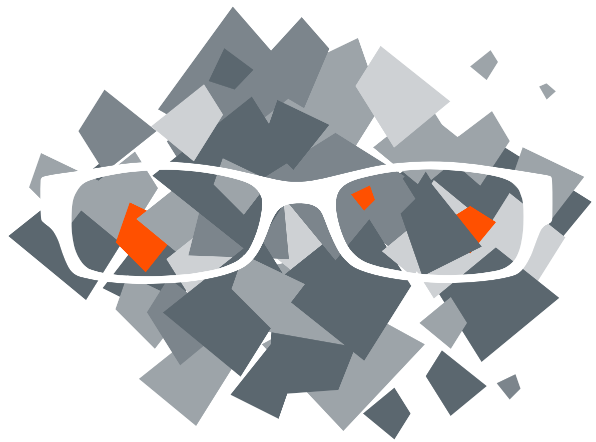
_Robots as natural companions. Future generations, "robotic natives", will see robots as the state of the art, as a lifestyle, or quite simply as normal. Just as commonplace as smartphones and the Internet, for example, are for the digital natives of today. They will have overcome the old human versus machine antagonism. The robot-oriented generation will shape a society that not only works differently, but also thinks differently. It will see the capabilities of robots as universal, networkable services that can be requested via the Internet and flexibly adapted to the requirements and desires of the individual at the click of a mouse. While nowadays robots are primarily known as work assistants in industrial processes, in the future they will be found in all areas of our daily lives as driverless cars, robo-furniture, carebots and a wide range of home and personal assistants. By 2050, a robot in every household will be part of everyday life.

Service Robotics

_Robots enter daily life. Even today, useful robotic assistants are making everyday life easier. Small, specialized service robots, for example, have long since established themselves in our private sphere. They are deployed as assistants in the home – vacuuming, mowing the lawn or cleaning windows. As yet, their capabilities are mostly limited to a single task. However, they do demonstrate one thing: collaboration between humans and robots works in everyday life. Thanks to the progressive development of service robotics, robots will shape daily life in the future in various ways. Whether it be as a nursing robot in clinical settings, as helpers for the elderly at home or as assistants in many other areas which today sound futuristic. For the robotic natives of tomorrow, service robots will be as self-evident as smartphones are for people of the present.

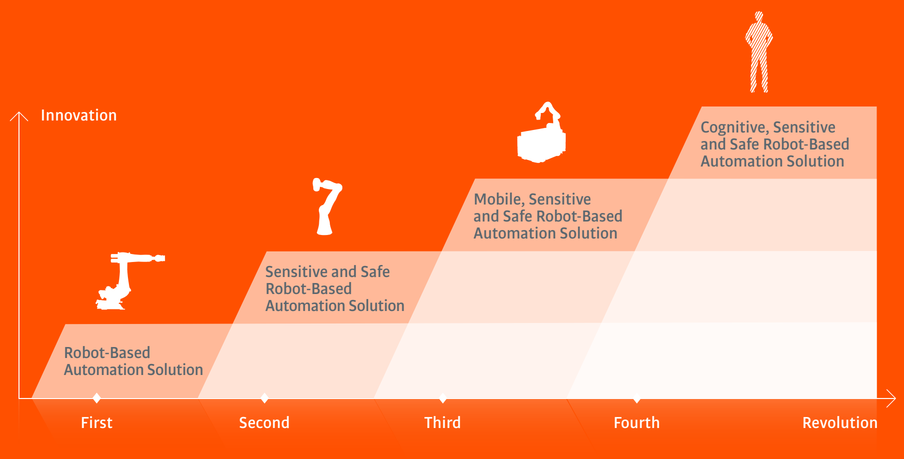
Smart Data

_Intelligent data exchange. If Big Data is the oil of the future, then Smart Data is the fuel that drives the production of the future. Currently, data are just data. To turn them into information, they must be interpreted. This is the step from perception (recognizing) to cognition (understanding). Books, for example, are at first merely collections of letters. They only become knowledge when they are processed and interpreted in the brain. KUKA is developing smart data technologies for the digital domains in the age of Industrie 4.0. In the context of intelligent automation, the central focus is on the topics of data communication, process modeling, machine learning, autonomous self-configuration and process optimization.



Four Robotic Revolutions

_The disruptive force of robotics. Robotics will change the world. In the next 50 years, it will have a disruptive influence similar to the one exerted by the Internet and information technology over the past five decades. The societal change that will accompany this is reflected in the “four revolutions in automation technology” postulated by KUKA. Alongside industrial robotics, which will continue to grow strongly with new, networked manufacturing processes, the area of service robotics – and ultimately robots – will become more established in private settings. In addition to ever faster response and development times for new robot generations, this step will also require a radically new approach.



Yesterday – The 1st robotic revolution

_Robot-Based Automation Solution. The age of robotics began in the 1960s and 1970s. Industrial robots brought greater efficiency and productivity to simple manual tasks such as lifting, spot welding and packaging. They began their triumphant advance in the automotive industry, spreading successively to other sectors. In this manufacturing environment, the robot operated in a fixed location within safety enclosures or zones to which humans had no access. Its tasks were clearly defined: relieving humans of monotonous work and assembling cars or other goods in large volumes as quickly and as precisely as possible.

Today – The 2nd robotic revolution

_Sensitive and Safe Robot-Based Automation Solution. What was science fiction just a few years ago is now a reality: robots and humans work hand in hand. Collaborative robots like the LBR iiwa developed by KUKA enable an entirely new relationship between humans and robots: direct and safe collaboration – without any safety enclosure. Where there is no fence restricting freedom, the way is open for new, highly efficient and far more flexible applications. The robot is now a machine that can be touched and with which interaction is possible. It will shape daily life in various ways in the future. Whether it be as a work assistant in industry, a service robot in the public sphere, a nursing robot in clinical settings, a helper in the home or in many other areas which today still sound futuristic.

On the starting grid – The 3rd robotic revolution

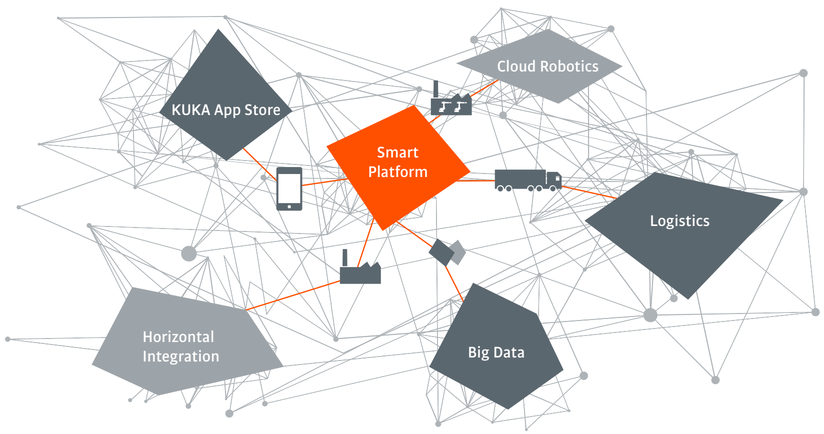
_Mobile, Sensitive and Safe Robot-Based Automation Solution. As autonomous mobile units, collaborative robots are able not only to react intelligently to their surroundings, but also to change their place of use. The ability to interact with people, machines or workpieces in varying locations gives mobile robots virtually boundless application potential. Mobile robots can already perform logistics tasks independently, collaborate directly with humans or quickly take on new tasks at different workstations. Essentially, there are as many potential applications as there are ideas for such applications.

In the future – The 4th robotic revolution

_Cognitive, Sensitive and Safe Robot-Based Automation Solution. If the robots of the future are characterized by artificial intelligence, they will reflect on and cognitively understand what they do. They will have the ability to interpret human language and gestures. On this level, robots will finally become active companions for humans. The “thinking” maid, Rosie, from the science fiction cartoon “The Jetsons” or Lieutenant Commander Data from “Star Trek” will indeed remain fiction for a long time, but in terms of their capabilities robots will come ever closer to these imagined characters.

Smart Factory

_Intelligent and self-organizing. The intelligent factory of the future is a production facility in which manufacturing systems, robots, logistics systems, products and their components are largely able to organize themselves autonomously. The smart factory is undergoing a paradigm shift towards an entirely new production logic: smart products, components, tools and machines are unambiguously identifiable, can be localized at all times and are aware of their history, their current status and multiple ways to the desired goal. With the smart factory's high degree of flexibility, customization with a batch size of 1 will become reality in the context of industrial mass production. To achieve this, the production systems must, on the one hand, be networked vertically, for example with business processes within factories and companies. On the other hand, they must also be linked horizontally across company boundaries – from the purchase order through to outbound logistics – to create distributed value creation networks that can be controlled in real time.

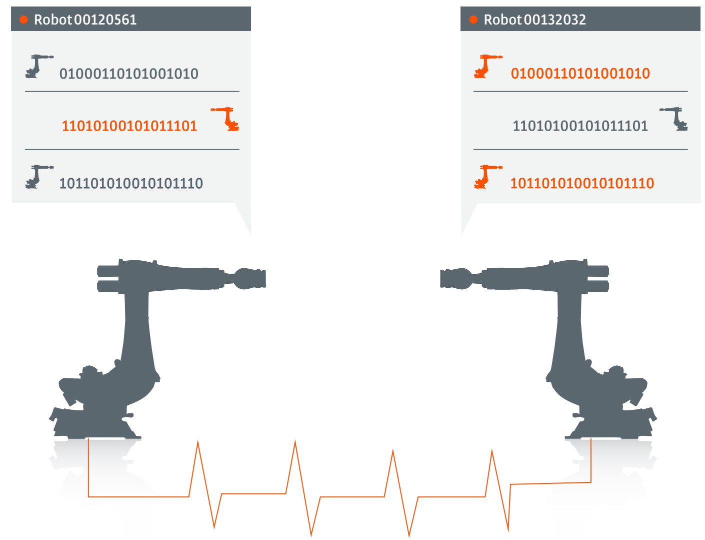


Smart Platforms

_Intelligent and flexible. New, intelligent platforms will be created for the implementation of Industrie 4.0. They will support collaborative industrial processes and use their services and applications to network people, things and systems. The result will ensure greater flexibility and a continuous flow of information: smart platforms will document the entire business process, work safely and reliably at all levels, and support mobile end devices and collaborative production, service, analysis and forecast processes along the entire digital supply chain. For the smart factory, KUKA already has modular software architectures in its portfolio, based on mainstream technologies and prepared for the entire evolutionary process of Industrie 4.0. The Java platform of KUKA Sunrise makes it ideally suited to future app-based programs.

Social Machines

_Interconnected. Intelligent. Flexible. Machines in production which are intelligently interconnected, communicate with one another and can instantaneously react to deviations and changes in an independent, situation-based manner are called social machines. They are part of the Industrie 4.0 vision. The underlying idea is that machines share their knowledge like in social networks – information about themselves as well as experiences and "lessons learned" from their processes. At the same time, social machines coordinate the information received and learn from the network too. Similarly to Facebook users, they independently obtain information from the Internet and connected social machine networks. Through swarm experience, they are aware of the best parameters for machining a particular material, for example, and they exchange them with "befriended" machines.

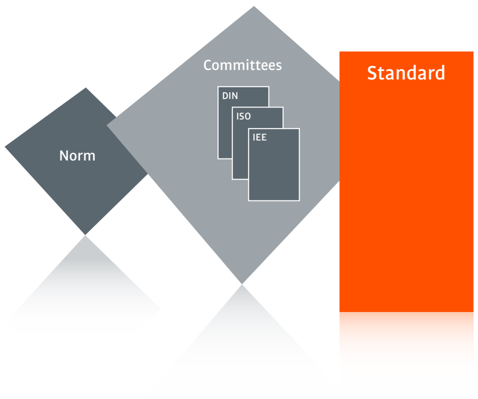


Standardization

_General requirements for reliable interaction. In the course of any technical evolution, different solutions, formats and approaches usually compete with one another – developed and propagated by various fractions, committees or companies. Only standardization, with its exact and binding definition of framework parameters and the possible interfaces, makes it possible to create appropriate expansions, counterparts and communication bridges to a new technology. Of particular importance in this context with regard to the implementation of Industrie 4.0 are the new definitions of safety in the area of human-machine collaboration and the standardization of interoperability in the area of data exchange. KUKA is striving for OPC UA to be established as one of the future standards. This protocol not only transports machine data, parameters, process values and measured data, but can also, in combination with other standards, define them semantically in a way that is machine-readable.

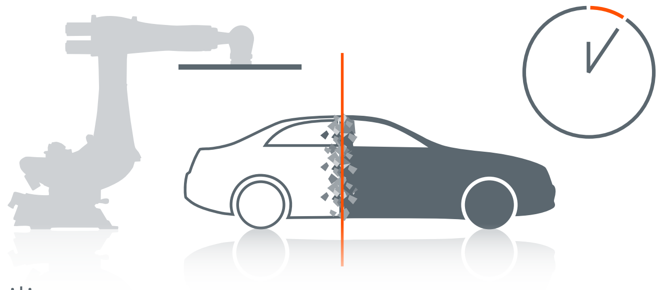
Standards

_The basis of all constructive cooperation. Standards are the elementary basis for breaking down barriers in the globalized world of Industrie 4.0. As a world leader in automation, KUKA sees itself as responsible for playing a key role in shaping the areas of standards and standardization. To this end, KUKA is driving forward the harmonization of communications, data exchange and safety, for example, in the field of direct human-machine collaboration. In this way, it is creating new standards to ensure interoperability in the smart factory of tomorrow. As one of the key players in the paradigm shift from the third industrial revolution to the fourth, KUKA is thus laying the foundation for successful cooperation between all those involved.



Time to Market

_Meeting customer requirements more quickly. The time to market denotes the length of time from development of a product to its availability on the market. In the factory of the future, this time, which is often decisive for the sales success of a product, will be significantly shortened. Positive effect: changing requirements and trends in increasingly volatile markets can be met with corresponding products much more quickly than previously.

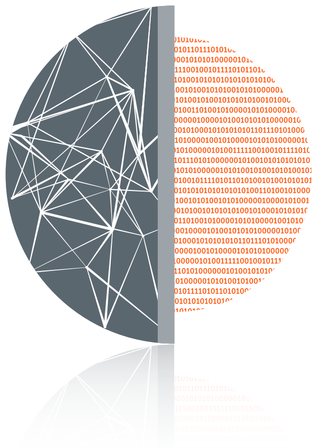


Traceability

_Keeping track. Traceability here refers to the ability to fully trace all raw materials, producers, upstream suppliers, individual parts or assemblies as well as the complete product and its consumers in the digital value creation chain. It is possible at all times to determine when, where and by whom the goods were produced, processed, stored, transported, used or disposed of. Irrespective of whether an individual part or a finished product is concerned, a distinction is made between two directions of traceability: from the manufacturer to the consumer and from the consumer to the manufacturer.

Verwaltungsschale (Administrative Shell)

_All data in a single shell. The Verwaltungsschale is the virtual image of a hardware or software component in a production process, containing all the specific production data. These data open the way to entirely new possibilities and added value in networked production. One decisive benefit is that all information – from CAD data and maintenance information through to configuration details – is located in one place without media discontinuity. Data and functions are available on the component itself, in the company network and/or in the cloud. This collection of information results in an all-encompassing knowledge which, once stored, can be made available for any user and any application.



youBot

_Realizing forward-looking ideas. The KUKA youBot allows researchers to work on a compact scale on major topics that impact the factory of the future. The KUKA youBot: a small, omnidirectional mobile platform on which one or two five-axis robot arms with two-finger grippers are installed. The arm and mobile platform can also be used independently of one another, however. The KUKA youBot targets research institutes and universities which can easily implement their own controllers and application ideas with the robot. Open interfaces make it possible to equip it with sensors, grippers and other accessories and to develop complex applications. The KUKA youBot offers researchers, teachers and students along with industry-based research and development departments an affordable hardware base for testing new ideas and scaling the acquired knowledge to other applications.

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